BeppoSAX discovery of a new Seyfert 2 galaxy: 1SAXJ2234.8-2541 ⋆

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Abstract. In the present work we report the *BeppoSAX* serendipitous discovery of the type 2 AGN 1SAXJ2234.8-2541 in the MECS field of view when pointing at the Seyfert 2 galaxy NGC7314. The source is optical identified with the bright (m_B=14.40) galaxy ESO533-G50 at redshift z=0.026. The source is clearly detected at energies above 4 keV but barely visible below this energy implying heavy obscuration intrinsic to the source. Spectral analysis indicates a column density of the order of 2-3 $\times$ 10^{23} cm^{-2} and a power law photon index compatible with values often seen in active galaxies. These X-ray characteristics suggest a Seyfert 2 classification for 1SAXJ2234.8-2541. Subsequent spectroscopy of the optical conterpart, ESO533-G50, performed with the ESO 1.52m telescope at La Silla Observatory, confirms the type 2 nature of this source and therefore its identification with the X-ray source. We also report the marginal detection of an iron line centered at 7.29 $\pm$ 0.47 keV and having an equivalent width of 464^{+636}_{-398} eV; although marginal, this result is indicative of the presence of warm material in the source. If instead the line is associated to cold material, we estimate an upper limit to its equivalent width of 290 eV. The overall characteristics of 1SAXJ2234.8-2541 strongly suggest that the source is Compton thin.

Key words: X-Ray: individual - selection - galaxies - Seyfert 2

1. Introduction

It is rather clear that in the soft X-ray band (0.5-2 keV), the major contribution to the Cosmic X-Ray Background (XRB) is due to the superposition of many discrete sources which are basically AGN (Hasinger et al. 1998, Schmidt et al. 1998). On the contrary, due to the lack, until recent years, of sensitive imaging instrument at higher energies (above 2 keV), the nature of the objects responsible of the hard (2-50 keV) XRB remains still dubious. Furthermore at higher energy the XRB shows a thermal-like spectrum (KT $\sim$ 40 keV) difficult to explain with any class of sources known so far. However, the current suggestion is that even at higher energies the main contributors to XRB are the AGN, but this time the heavy obscured ones. This is in line with both the theoretical expectations (Setti and Woltjier, 1989; Matt and Fabian, 1994; Comastri et al. 1995) and the observational findings (Bassani et al. 1999; Fiore et al. 1999). A great contribution to this issue has been given both by ASCA (Della Ceca et al. 1999, Boyle et al. 1998, Ueda et al. 1998) and *BeppoSAX* (Giommi et al. 1998a,1998b, Fiore et al. 1999) and more recently by Chandra (Mushotzky et al 2000). In particular the good sensitivity of the *BeppoSAX* MECS detectors (5-10 keV flux limit of $\sim$ 0.002 mCrab in 100Ks, Boella et al. 1997a) and their improved point spread function (PSF), provide an ideal tool for discovering hard X-ray sources, i.e. those with emission above 4 keV. A step ahead in this context has been made with the *BeppoSAX* High Energy LLarge Area Survey (HELLAS) (Fiore et al. 1998a,1998b). The HELLAS survey has so far catalogued 180 sources (Fiore et al. 1999) in about 50 deg^2 of sky down to a limiting flux of 5×10^{-14} erg cm^{-2} s^{-1}. Most of the sources are identified with AGN which corresponds to resolving about 30% of the hard XRB. Furtermore, a great majority of them turned out to be absorbed by column densities in the range 10^{22}-10^{23} cm^{-2} even though they may be highly different in their optical and near-infrared properties. Fabian (2000) has recently pointed out that if absorbed AGN are the major contributors to the hard XRB then about 85% of the accreation power in the Universe is absorbed. Identification of hard X-ray sources and study of their X-ray

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⋆ Partially based on observations collected at the European Southern Observatory, Chile

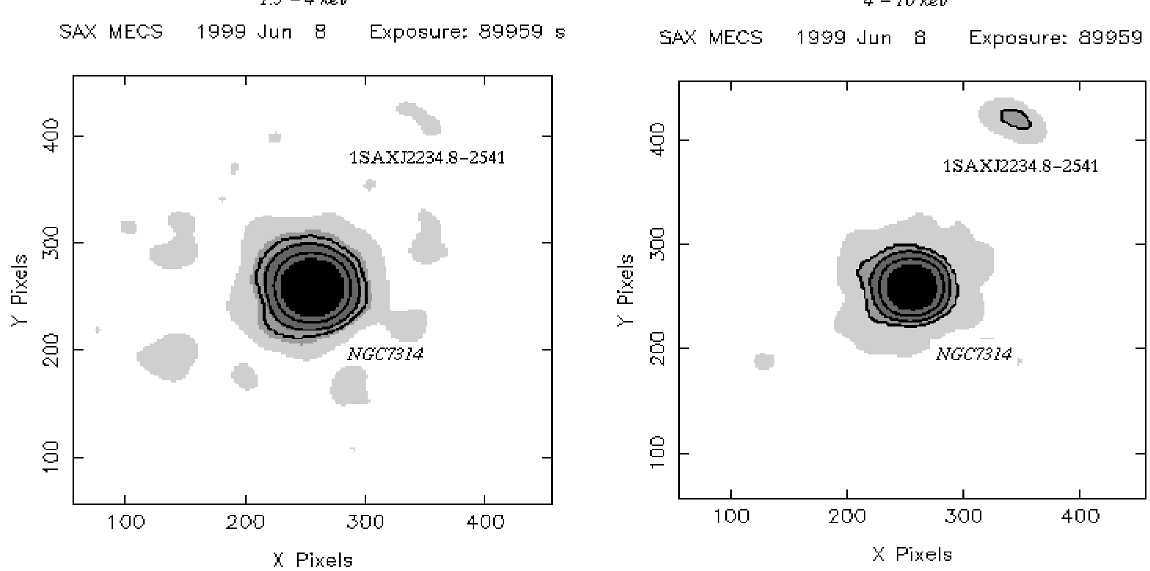

Fig. 1. *BeppoSAX* MECS image when pointing at NGC7314 in two different energy bands: 1.3-4 keV (left side) and 4-10 keV (right side).

characteristics is therefore important in order to investigate all the above mentioned issues. In this paper we report the *BeppoSAX* serendipitous discovery of a type 2 AGN: 1SAXJ2234.8-2541. Its absorbed type 2 nature was firstly revealed by the X-ray data and after confirmed by the optical spectroscopy. We anticipate that the new generation of X-ray observatories like Chandra and XMM will discover many more sources similar to 1SAXJ2234.8-2541 and few others recently reported in the literature (Della Ceca et al. 1999, Fiore et al. 1999) making these results reference cases for future work.

2. X-Ray Data Analysis

The *BeppoSAX* X-ray observatory (Boella et al. 1997b) is a major programme of the Italian Space Agency with participation of the Netherlands Agency for Aereospace Programs. This work concerns results obtained with the Medium Energy Concentrator Spectrometers (MECS; Boella et al. 1997a). The data from the LECS (Low Energy Concentrator Spectrometer) were not available whereas the data from PDS (Phoswich Detector System) cannot be used due to contamination from the main target of the observation which was pointed by the BeppoSAX Narrow Field Instruments (NFI) from June 8th to June 10th, 1999.

2.1. Imaging Analysis

The reduction procedures and screening criteria used to produce th linearized and equalized (between the two MECS) event files were standard (Guainazzi et al. 1999) and took into account the offset position of the source.

1SAXJ2234.8-2541 was discovered in the MECS field of view when pointing at the Seyfert 2 galaxy NGC7314. Figures 1 shows the MECS image in two different bands (1.3-4 keV) and (4-10 keV) with overlaid a contour plot indicating the intensity level of the X-ray emission. The hard X-ray nature of 1SAXJ2234.8-2541 is clearly evident: the source is almost undetectable in the soft X-ray band on the left side of the figure while it is well detected at a confidence level of 10 σ in the hard X-ray band on the right side. There are no pointed ROSAT observation containing this source, nor is this object detected in the ROSAT all sky survey. In the X-ray band the source is located at (J2000) RA = $22^h\ 34^m\ 53.6^s$ Dec = $-25° \ 41' \ 2.6''$, 25 arcmin northeast of the target source; the uncertainty associated with the source position is 1 arcmin (90% confidence level). A fairly bright (m_B = 14.40) spiral SB galaxy is present in this error circle and is identified with ESO533-G50 at redshift z=0.026. Figure 2 shows the ESO Digitized Sky Survey image centered on ESO533-G50 with superimposed the X-ray positition of 1SAXJ2234.8-2541 and the associated error circle. No much data are available on this source from the literature, although the galaxy is catalogued as ringed (Buta et al. 1995, see also figure 2) probably as a result of a galaxy-galaxy and/or intergalactic gas-galaxy collisions. The probability of finding such a bright galaxy within an error box of 1 arcmin is $\sim 1 \times 10^{-3}$ (Giommi et al. 2000). This combined with the data discussed in this paper strongly support the identification of 1SAXJ2234.8-2541 with the ESO galaxy.

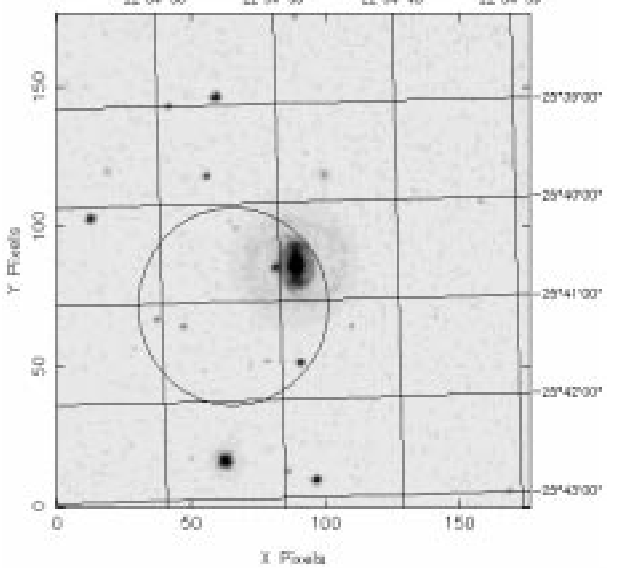

Fig. 2. DSS image of the field centered on ESO533-050. The circle represents the 90% confidence level error box of 1 arcmin radius while the center of the circle is the X-ray position of 1SAXJ2234.8-2541.

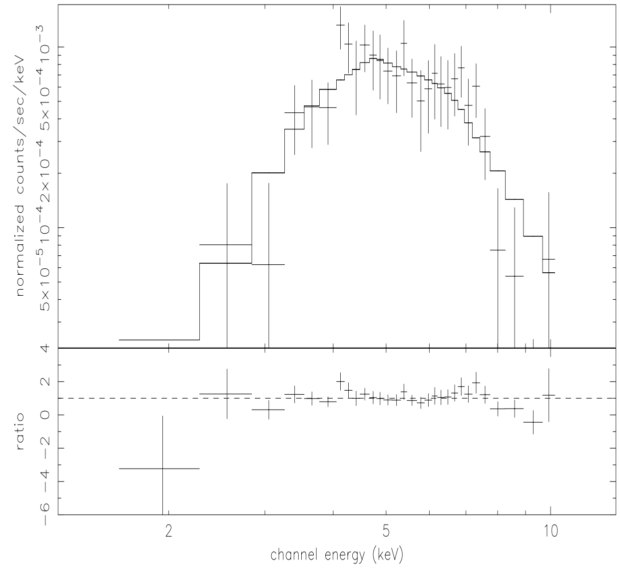

Fig. 3. BeppoSAX MECS data of 1SAXJ2234.8-2541 fitted with absorbed power law (top); the residuals between the data and the model are plotted at the bottom.

2.2. Spectral Analysis

The effective on-source exposure time was 89959 s. Spectral data were extracted from regions centered on 1SAXJ2234.8-2541 with a radius of 4′ and the background subtraction was performed by means of blank sky spectra extracted from the same region of the source. The net source count rates were $(3.11\pm0.26)\times10^{-3}$ cts/s in the (1.8 - 10.5 keV) MECS energy range.

MECS data were rebinned in order to sample the energy resolution of the detector with an accuracy proportional to the count rate. The spectral analysis has been performed by means of the XSPEC 10.0 package, and using the instrument response matrices released by the BeppoSAX Science Data Centre in September 1997. All quoted errors correspond to 90% confidence intervals for one interesting parameter ($\Delta\chi^2 = 2.71$). Source plus background light curves did not show any significant variation and therefore the data from the whole observation were summed together for the spectral analysis.

All the models used in what follows contain an additional term to allow for the absorption of X-rays due to our Galaxy that in the direction of 1SAXJ2234.8-2541 amounts to 1.5×10^{20} cm^{-2} (Dickey & Lockman, 1990). We first fit the data with a single power law to search for any extra feature: this fit gives an unusually flat spectrum ($\Gamma = +0.7$) and marginally acceptable reduced $\chi^2 = 2.3$ for 28 d.o.f.. We also try a thermal fit using a Raymond Smith model but also this gives a too high temperature (greater than 10 keV) and an unacceptable fit. We then introduced intrinsic absorption in the source: in this case the fit is satisfactory (χ^2/ν=21.32/27) and results in a spectrum having a photon index Γ=$2.98^{+1.58}_{-1.21}$ and an absorbing column density N_H=$(3.1^{+1.5}_{-1.2}) \times 10^{23}$ cm^{-2}. The introduction of this extra parameter provides an improvement in the fit ($\Delta\chi^2$=43.9 for one additional parameter) which is significant at more than 99.99% confidence level. If the power law index is fixed to 1.9, a value more appropriate to an AGN X-ray spectrum, the column density reduces to 2.2×10^{23} cm^{-2} and the χ^2 is 23.41 for 28 d.o.f. The 2-10 keV observed flux is 1.5×10^{-12} erg cm^{-2} s^{-1} corresponding to an absorption corrected luminosity of 1.2×10^{43} erg s^{-1}. The source count rate spectrum and the data to model ratio for the absorbed power law fit with index fixed to 1.9, are shown in figure 3. Inspection of figure 3 indicates that some residual emission may be present around 6-8 keV suggesting the introduction in the fit of a narrow gaussian emission line. The line turns out to be centered at 7.29±0.47 keV and has a rest frame equivalent width (EW) of 464^{+636}_{-398} eV. The addition of this line provides a slight improvement in the fit ($\Delta\chi^2$=3.5 for two additional parameters) which is only significant at 87.5% confidence level. If the line width is allowed to vary, the best fit value is $0.28^{+0.54}_{-0.28}$ i.e. consistent with being zero. The confidence contours of the line energy versus normalization (figure 4) indicate that the line is also compatible with a K_α line from cold material at 6.4 keV. However, fixing the line energy at 6.4 keV provides an upper limit of 290 eV to the equivalent width of this line and does not eliminate the residuals observed in the data to model ratio in figure 3. We therefore conclude that the observed

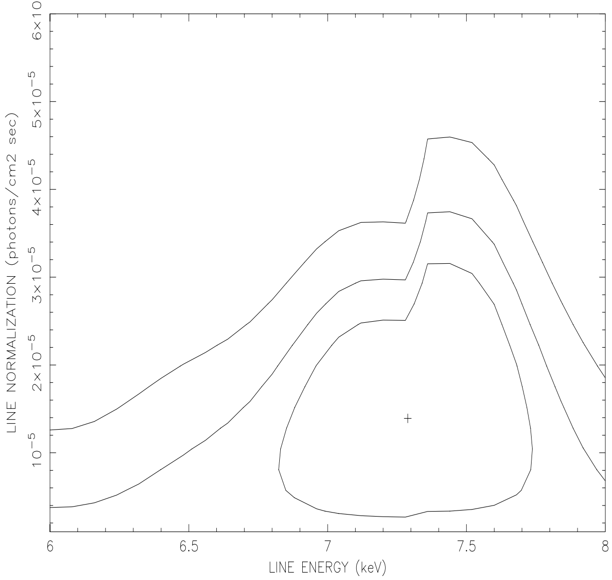

Fig. 4. BeppoSAX confidence contours of the normalization of the line vs the Gaussian line. The contours are 68%, 90% and 98% confidence level.

line, if confirmed, is more likely associated to warm than cold material.

3. Optical Data Analysis

In order to optically classify our source by applying the standard line ratio diagnostic (see for example Tresse et al. 1996), spectroscopy covering 3400-5400 $\mathring{A}$ region is needed. Therefore we performed such a type of observation as soon as was possible. Optical data were obtained on the night of November 2, 1999, using the Boller & Chivens spectrograph on the ESO 1.52-m telescope at the La Silla Observatory (Chile). The spectrograph was equipped with the holographic grating #33 and the Loral #39 CCD camera. The configuration results in a nominal dispersion of $\sim$ 1Å/pixel. Data have been reduced according to the standard procedure using the *Starlink* software packages CCDPACK (Draper 1998) and FIGARO (Shortridge et al. 1997). The extracted spectrum is displayed in figure 5. Unfortunately conditions were not photometric and therefore no flux calibration was attempted.

The spectrum is typical of a low-redshift galaxy, except for the strong emission lines corrisponding to forbidden transitions of oxygen. Hβ cannot be seen in emission at the expected wavelength of $\lambda 4491\mathring{A}$ implying that it could be extremely weak or absorbed. The fact that the only strong lines that we can detect are forbidden, strongly suggests that ESO533-G050 is a type 1.9-2 Seyfert (see Osterbrock 1981 and Osterbrock and Dahari 1983 for similar examples). Because we cannot see Hβ, we cannot formally apply any of the diagnostic ratios, such as its position in the

in such a diagram, Seyfert 2 galaxies occupy the top-right part, with high values of both O[III]/Hβ and O[II]/Hβ. 1SAXJ2234.8-2541 seems to have extremely high values for these two indices and therefore should be classified along with these sources in agreement with the X-ray spectroscopic results.

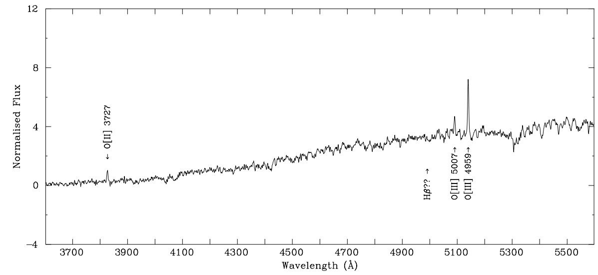

Fig. 5. Optical spectrum of 1SAXJ2234.8-2541 in the 3400-5400 $\mathring{A}$

4. Discussion

Having assessed that our object is a type 2 Seyfert, the next step is to determine what kind of Seyfert 2 it is, i.e. Compton thin or Compton thick. The column density measured exclude that the source is thick (i.e. the intrinsic N_H is less than 1.5×10^{24} cm^{-2}). However, observations of Seyfert 2 limited to a restricted energy band such as is the 2-10 keV band, has provided wrong estimates of the column density in a few occasions in the past (Cappi et al. 1999a, Turner et al 2000, Vignali et al. 2000). Therefore an independent method to determine the nature of the hidden nucleus must be used: following Mulchaey et al. (1994) the IR to X-ray ratio is a valid indicator of the Compton thinness/thickness of the source. Although the source was not detected by IRAS, we estimated an upper limit to the (25-60 micron) flux using data obtained within 1 degree from the source and applying Mulchaey et al. (1994) formulation. The value obtained (2.3×10^{-11} erg cm^{-2} s^{-1}) provides a $\log(F_{IR}/F_X)$ of ≤ 1.7 and, since in Compton thin cases this value is expected to be $\sim$0.9, our result support the Compton thinness of the source. Compton thin Seyfert 2 galaxies are generally characterized by an iron line emission produced either by transmission and/or reflection by cold absorbing material in the source, i.e. by a dominant line at 6.4 keV. In the first case, we expect an equivalent width of 100-200 eV for a column density of 3 $\times$ 10^{23} while in the case of reflection the width increases to about 400 eV (Turner et al. 1997) for the same amount of absorption. Our upper limit of 290 eV on the 6.4 Kα line marginally discriminate between these two possibilities suggesting that the reflection in this source is negligible or absent; also our spectrum is too steep to allow the photon index to a value smaller than 1.9. On the other hand, the line could be at ∼7 keV, thus likely to come from a highly ionized medium in the source. Ionized lines are generally observed in Starburst galaxies and Liners (Cappi et al. 1999b and Pellegrini et al. 1999, 2000 , Terashima et al. 1999) and also in Compton thick Seyfert 2, but are rarely seen in Compton thin type 2 objects (only 20-30% of the sources in the ASCA sample analyzed by Turner et al. 1997 show iron lines from ionized material and of these the majority are indeed Compton thick sources). A line at 7.06 keV could be due to Fe Kβ fluorescence associated to the 6.4 keV line; however the expected Kβ/Kα ratio is 1:9 while in our data the Kβ line would dominate over the Kα one. Obviously a deeper observation of 1SAXJ2234.8-2541 is necessary to confirm the presence of the line and its energy; this may be worth given the paucity of Compton thin Seyfert 2 having warm material at the nucleus and the serendipitous discovery of the source, which makes it relevant to the synthesis of the hard XRB.

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